Chapter 8. Fishery Research Protocols

Fisheries sustainability is an elusive goal for marine resource managers. The cornerstone of effective resource management is a comprehensive, spatial-temporal knowledge of the resource. However, there is a paucity of this knowledge for most marine resources, mainly because of our limited powers of direct observation. In the ocean, most processes occur out of our view, thus our knowledge of marine communities, species abundance patterns, and ecological interactions is fragmentary.

Fishery research is necessary to understand the many complex factors that contribute to the health of our resources and fisheries. This research is needed to provide management with guidance in making decisions to ensure sustainable fisheries. The MLMA recognizes the importance of research and requires all FMPs to contain fishery research protocols (§7081 FGC). These research protocols must:

- describe past and ongoing monitoring of the fishery;
- identify essential fishery information (EFI) for the fishery, and if any is lacking, identify resources and time to acquire it; and
- indicate steps to monitor the fishery and obtain EFI.

Little biological information on market squid has been gathered in the past 30 years. Thus, EFI is lacking in many areas. Future research should work toward acquiring this EFI, and involve collaborative efforts of the fishing industry (both commercial and recreational) and qualified university or private fisheries research institutions. In accordance with MLMA, this chapter describes fishery research protocols designed to implement the MSFMP; it identifies gaps in the current knowledge of market squid stocks and the fishery, and the steps needed to obtain this information for implementation to be successful.

8.1 Essential Fishery Information

The MLMA provides an opportunity for fishermen, scientists, fishery managers, conservationists, and other concerned constituents to develop a new approach for managing our marine resources. The MLMA recognizes the importance of a collective body of biological, ecological, physical, economic and social information known as "essential fishery information" (EFI). This information is critical for the sustainable use and successful management of the State's marine resources. The MLMA calls for the Department to base FMPs on the best available scientific

information (§7072(b) FGC). In addition, any gaps in EFI of a fishery are to be identified, along with steps to close those gaps (§7081 FGC). Essential fishery information generally falls into two broad categories based on how the data were obtained: fishery-dependent (related to the take of fishermen), and fishery-independent information (data gathered independent of the fishery).

8.1.1 Grouping Essential Fishery Information

There are numerous parameters that comprise EFI. In an attempt to identify which EFI the Department should focus its resources on, nine broad EFI groups were created. It is important to emphasize that these groups are not mutually exclusive of one another since one group may include components that also fall under another. These groups were formed so EFI could be prioritized based on what information was most crucial for management. The nine EFI groups are:

Age and growth characteristics
Age and growth studies typically measure how long a species lives, the age at which it reproduces, and how fast individuals grow. This information is very important to determine a population's ability to replenish itself, at what rate it might be harvested, and when individuals will reach a harvestable size. Changes in the age structure and growth rate of a population also serve as indicators of that population's health. This information is often essential for stock assessments and models that guide management strategies. Specific EFI includes length/weight ratios, longevity, age/length ratios, age/size at sexual maturity, and age/length at recruitment into the fishery.

Distribution of stocks
A stock is a population unit that is selected for management purposes. It may be defined based on its ecology, genetics, and/or geographic separation. Discrete stocks of a given species may have very different growth rates, reproductive schedules and capacity, and even ecological relationships. Stock distribution refers to where a stock is found, and is important in addressing jurisdictional issues. Specific EFI includes the depth and geographic range of a species, the amount of gene flow and genetic structure of the stock, and whether stocks are separate or continuous.

Ecological interactions
This information identifies the interaction of fishes within the environment, habitat, and ecological community. Ecological relationships include the effects of oceanographic regimes and anthropogenic perturbations on physiological, energetic, or behavioral variables; ecological niches and placement in food webs (prey and predators); density-dependent and density-independent interrelationships within and among species; and the importance of essential fish habitat and habitat quality to a species. Estimation of any ecological relationship demands a species-specific within-habitat approach due to environment and organism cross correlations.

Estimates of abundance

This information helps to determine how many individuals of a population are out there and available to the fishery. This information is essential for all predictive modeling of marine resources. Estimates of stock size can be determined through direct (e.g., surveys) or indirect (e.g., examination of the exploitation history) means. Specific EFI includes relative densities of target and non-target species, habitat-specific absolute densities, length frequency distributions, relative density estimates of life stages (i.e., eggs, larvae, young-of-the-year, juveniles, or adults), recapture rates of tagged fish, and catch-per-unit-effort information.

Movement patterns

This information identifies the spatial distribution of fish and their residence time in specific habitats. Many species may exhibit movement patterns that are associated with specific oceanographic conditions. Certain species may aggregate in specific areas for spawning, move in predictable patterns, or move to certain locales that make them especially vulnerable to harvest. Insights into the movement patterns of fish are important to the development of management strategies based on regional catch quotas or marine protected areas. Specific EFI includes the home range, homing ability, seasonal migrations, environmental cues, and spawning grounds of a species.

Recruitment

Recruitment refers to a measure of the number of fish that survive to a particular life stage, and is often used to predict future population size. In this context, recruitment refers to both recruitment to the fishery and recruitment to the population. Many species depend on successful recruitment events for replenishment of the stock. Recruitment success can be highly variable because it depends on the proper combination of many factors. As a result, sustainable harvest of the fishery may depend on only a few strong cohorts (born the same year) to provide harvestable stocks until the next successful recruitment event. Resource managers must consider this variable recruitment success when setting harvest levels by allowing sufficient portions of stocks to “escape” harvest and provide spawning biomass for future recruitment successes. Specific EFI includes the duration and distribution of egg and larvae, size and timing of settlement, and annual cohort success. Information on the availability of habitats and levels of predators and prey items is also important.

Reproductive characteristics

This information helps describe the reproductive potential of a fish stock and its ability to replenish itself. Understanding key reproductive characteristics allows managers to set appropriate open and closed seasons as well as opened and closed areas based on important spawning habitat. This information is also crucial in selecting size/slot limits, escape mechanisms for traps, and mesh-size restrictions. Specific EFI for a species includes the number of eggs released, size at maturity, fertilization and spawning period, geographic spawning area, and the nature of mating systems.

Total mortality

This information refers to all removals of fish from the biomass, and is used to predict how many animals remain to reproduce and replenish the population. Mortality figures are essential for stock assessments and models to determine the number or weight (biomass) which may be safely harvested from a population or stock on a sustainable basis. Total mortality is traditionally separated into natural mortality and fishing mortality. Natural and fishing mortality rates comprise the sum of all individuals removed from a population over a fixed period of time (often over one year). Fishing mortality is the number of animals which are removed from the population by fishing. Natural mortality refers to all other forms of removal of fish from the population such as predation, old age, starvation, or disease. Specific EFI includes catch data by species and area, amount and sizes of discarded catch, landings by gear type, and survivability of fish that are released.

Socioeconomic

The economic stability of coastal communities and quality of life may be affected by changes in activities related to recreational fishing, or commercial fishing and processing. These changes may be caused by indirect factors or regulatory changes that directly affect fishing activities. Indirect factors include triggers from consumer or financial markets, such as 1) changes in consumer demand due to the favorable pricing and supply of a substitute item for a fishery product(s), 2) inflation, and, 3) tax changes that affect business investments or activities. These effects may be manifested locally through resultant changes in business output, employment, population, and public service demand. The four broad categories of socioeconomic information include:

1. Employment

Overall, impacts to local community earnings and employment can be gauged using input-output multipliers to project the changes to local personal income and the number of local jobs. This procedure takes the direct change in final demand for an industry product or service in revenue or sales dollars and multiplies this direct change by a total income coefficient to estimate total change in local personal income. Similarly, multiplying the direct change by an employment coefficient yields estimates of changes in the number of local jobs.

2. Expenditures

Regulatory changes that directly affect recreational or commercial fishing revenues in local economies have a downstream effect on other economic sectors which receive and re-spend those revenues. This turnover refers to the number of times a dollar changes hands in the local economy. Output multipliers are used to describe the turnover effect and interrelationships between the basic-sector and downstream business sectors in the local economy.

Additionally, changes that directly affect end-user demand for recreational fishing activities or commercial fisheries products may change end-user spending patterns.

Depending on the nature of end-user demand for a given service or product, end-users may spend less if the quantity or quality of the service or product is decreased. Conversely, we would expect end-users to spend more if the quantity or quality was improved. These changes in spending patterns may also affect purchases of related or ancillary goods or services provided in the local economy.

Lastly, the costs (usually expenditures) of production of a good, service, or activity provide a means to compare the relationship between resources used to benefits derived. Often, this is expressed as the benefits-to-cost comparison. In the case of commercial fishing activities, by monitoring costs of production at various levels of output, we can define production where we have maximum economic benefit (or "profits"). This is important in creating harvest guidelines which foster optimum economic yield and economic efficiency in the fishing fleet. Economic efficiency equates to cost and waste minimizing practices.

3. Resource Demand
Changes in the quantity or quality of available fishery-related goods or services affect the individual end-user's demand for those goods or services. How much this demand may be affected depends on individual income, tastes, preferences, and the accessibility to substitute goods or services. The aggregate demand, based on the combined responses of individuals to changes in a good or service, yields an overall demand function for a good or service. This demand function is used to predict the reactions of end-users to changes in the quantity or quality of goods or services, and to estimate the relative value and benefits end-users derive from a good. Consequently, the effects of in-season adjustments to harvest limits, or changes in bag limits, can be projected in terms of the anticipated response of the target group of end-users, as well as changes in the corresponding revenue streams.

4. Revenue
This category includes revenue from the sale of local goods or services within the community and those goods or services which are exported out of the community. Revenue information allows resource managers to assess how changes in resources or regulations may affect industry-sector revenues and ultimately, the local community's economic output and vitality. Revenue generated by fishery-dependent activities (e.g., by commercial landings, recreational direct expenditures, or end-user consumption of commercial products) provides basic information for calculating contributions to local economies and a means to compare relative values of goods and services derived from the fishery.

8.2 Past and Ongoing Monitoring of the Commercial Fishery

8.2.1 Past Fishery-Dependent Monitoring
Fishery dependent data for commercial market squid fishery have been collected since 1927. Commercial data in the form of landing receipts or "fish tickets," which are filled out when the catch is sold to fish businesses or by fishermen selling directly to the public, are a major source of information on the amount landed,

landing location, gear used and value of the catch. Landing receipts to date have provided little essential fisheries information other than a broad idea of when and where fishing activity occurs and amount of squid landed. Logbooks are another useful tool for tracking fishing activity and one that helps to supplement and data gathered from landing receipts. In the case of market squid, logbook information is gathered from the vessels and lightboats. These logbooks should provide a measure of effort by the fishery, a value necessary for a biomass estimate.

In addition to the collection of passive data sets, the Department has actively collected fishery dependent data on market squid through a dockside sampling program. The typical data collected are species identification, size, weight, sex, age from statoliths, maturity through gonad and mantle tissue collection, and fecundity.

8.2.2 Problems with Past and Ongoing Fishery-Dependent Monitoring

Currently, some fishery-dependent data suffer from being of limited use or inaccuracies. Fishery-dependent monitoring, through the use of landing receipts and logbooks, does not provide adequate information about fishing location. The fishing blocks used by the Department are 10 nautical miles (nm) by 10 nm representing 100 square nautical miles of area. The size of the blocks is too large to identify specific fishing locations and/or populations of market squid and does not lend itself to ecosystem management. In addition, the tendency among some fishermen is to alter the location data to prevent identification of “secret” fishing sites and a less than accurate block may be recorded on landing tickets. Spatially explicit understanding of fishing spots can lead to identification of stocks, localized fishing mortality, and areas of stock depletion - all of which are important elements for proper fishery management. .

In general, fishery-dependent data when used alone have performed poorly in predicting stock decline (National Research Council 2000). Imprecise recording of fish landings, which are documented by fishery-dependent data, can actually hide precipitous declines in fished populations (Karpov et al. 2000). Vigorous and refined ecosystem-based sampling is needed to help adequately address the complex issues now faced by fishery managers.

8.2.3 Past Fishery Independent-Research

Fishery-independent data are important because they yield estimates of the abundance and distribution and the life history characteristics of the stocks that are more objective than those obtained from fishery-dependent data.
Fishery-independent data: 1) provide measures of the relative abundance, trends, and estimates of the size and age structure of fish stocks which are not affected by fishing practices or management regulations; 2) calibrate trends in fishery-dependent estimates and tune assessment models; and 3) encompass a broad suite of information on the biological community, the physical environment and the ecosystem as a whole, that cannot be obtained directly via fishery-dependent

measures. These data facilitate alternatives to classical demographic modeling (e.g., bioenergetics, mass-balance, and dynamic modeling). More powerful and sophisticated models can enhance the accuracy of stock estimates and the predictability of fishable biomass.

There have been few fishery-independent studies on market squid. The Department began intensive research into the biology of market squid in 1998 concurrent with the passage of SB 364. These studies have provided preliminary information on paralarval and market squid distribution when not on the spawning grounds, characterization of spawning habitat and their reproductive potential.

8.2.4 Problems with past and Ongoing Fishery Independent-Research

Fishery-independent research has, and continues to be, conducted by a multitude of organizations through a diverse set of funding sources. Unfortunately, the bulk of the research suffers from the following problems:

- It has limited spatial coverage;
- It has been collected using a multitude of techniques;
- It has been conducted on some subset of the ecosystem;
- It cannot easily be compared with other data sets; and
- It can be very expensive.

However, the Department market squid research program was funded primarily through substantial permit fees and has been coordinated for comparability throughout California. This synchronized research approach is effective and should be continued.

8.3 Current Knowledge of Essential Fishery Information

Currently, EFI for market squid is limited for management purposes. More data and analyses are needed to assess the biomass of the stock, life history, ecological interactions, and socioeconomics. A description of the data currently available on market squid is outlined below:

<u>Reproductive characteristics</u>
Some of the reproductive characteristics of market squid have been identified (Macewicz, et al. 2002). The potential fecundity has been characterized and is utilized in the egg escapement method. Preliminary information indicates that female squid taken in the fishery have found that 41.7% of reproductive potential of the catch escaped capture. The temperature range for spawning squid has been identified through the use of a remotely operated vehicle (ROV) and is most often in the range of 50 to 57º F.

<u>Age and growth characteristics</u>

The lifespan of market squid has been calculated based on the recent research. Preliminary research indicates that market squid harvested are between four and 10 months in age and new cohorts enter the fishery at least seven times a year. Length-at-age and length-weight relationships have been calculated, but need to be verified by further age and growth studies. The ageing technique of using statoliths needs to be validated throughout the lifespan of market squid.

Recruitment

Paralarval studies (Zeidberg 2002) may provide information to predict recruitment into the fishery and identify spawning areas not targeted by the fishery. Three years of data have been collected and published in a marine biology journal.

Mortality rates

The current rate of natural and fishing mortality for market squid is largely unknown. Ageing studies have started to produce better estimates. A pilot project will start August 2002 to examine egg mortality.

Ecological interactions

No statewide coordination exists for studies of ecological interactions of market squid . Consequently, little is known about the region-specific effects of oceanographic regimes and anthropogenic effects on the physiological, energetic, and behavioral characteristics of market squid, or the species that they interact with as prey, predators, or competitors.

Socioeconomic

Adequate information on employment, expenditures, and revenues for certain basic-sector industries are readily available or can be derived from existing sources. Such sources include the periodic surveys and reports prepared by the Bureau of the Census, the Bureau of Labor and Statistics, the Bureau of Economic Analyses, the USFWS, the California Department of Fish and Game, and local institutions and academic affiliates. Combined information from these sources allows analyses of impacts or contributions to local economies by commercial fishing activities. However, these sources do not provide adequate information relevant for a thorough analysis of the California market squid fishery.

8.4 Research Needed to Obtain Essential Fishery Information

The following research needs are necessary to fill market squid EFI gaps identified above. The overall goal is to bring our knowledge of market squid up from data-poor to data-rich; data-poor management using a MSY proxy should be considered a temporary solution while an accurate method to assess market squid biomass is pursued.

Fishery-dependent Data Research

- Monitoring of Squid Fishery through port sampling:

Port sampling to get biological information on squid taken in the fishery
Port sampling to monitor the fishery to detect potential shifts in the fishery which can have deleterious effects on the population based on the egg escapement method (EE) as a proxy for MSY;
Confirm that no shifts in fishery occur (i.e., a shift to pre-spawning adults would invalidate EE
Changes in growth (environmental changes)
Changes in the type of fishery

- Analyze logbooks to determine fishery effort

<u>Fishery-independent Data Research</u>

- Develop a model to estimate market squid biomass
- Examine bycatch, especially for egg case removal and disturbance
- Egg distribution surveys using ROV
  - Provides visual confirmation of squid spawn in specific areas (verify EE)
  - Provides information on spawning habitat, distribution of egg cases
  - Need to evaluate if abundance or frequency of eggs observed are applicable to population models
- Research questions which need verification under Amendment 10 MSY proxy (Egg escapement model)
  - Need additional "virgin" female squid for histological studies to improve and enhance current egg escapement method
  - Investigate rate of mantle thinning
  - Calculate number of times individual squid spawn
  - Determine how long individual squid are vulnerable to the fishery on spawning grounds
  - Evaluate if there are differential growth and/or fecundity rates between the northern California and southern California fisheries
- Growth Rates –Ageing of Market Squid
  - Need to verify technique
  - Need to validate daily growth rings at all stages of squid life cycle

<u>Additional Market Squid Fishery-Independent Research Not Yet Funded</u>

- California Cooperative Ocean Fisheries Investigations (CalCOFI) cruises from 1978 through 1998 larval squid numbers need to be analyzed
- Consider possible interaction between predators and lights (sea lions appear to be attracted to lights for squid)
- Analyze diet using port samples to monitor dietary requirements of squid population
- Examine densities of egg cases both inside and outside of fishing areas
- Determine if there are different stocks of market squid in California using genetic markers and examine the potential of using squid eggs for genetic analysis
- Determine the distribution of market squid and migration
- Investigate squid spawning behavior

- Continue seabird/fishery disturbance research; evaluate effectiveness of shields and wattage restrictions
- Study the dynamics of eggs (i.e., how to eggs get oxygenated)
- Conduct research surveys in October to November to provide early season data for southern California fishery
- Determine natural mortality values
- Paralarval index of abundance may be useful as an index of abundance to model the squid population – combine with CalCOFI cruises if possible

Other

- Create a database of spawning areas (fishing, research, surveys)
- Consider how to archive data and samples
- Expand socioeconomic data collection

8.5 Steps to Monitor the Fishery and Obtain Essential Fishery Information

The Department is currently monitoring the market squid fishery through fishery dependent programs and some fishery-independent research. Fishery dependent programs include the port sampling program that allows the Department to determine the characteristics of harvested squid, shifts in the fishery and estimate egg escapement. Another fishery dependent program is the logbook program that will estimate fishery effort and provide exact locations of fishery activity. The fishery independent research taking place is focused on increasing the sample size for the egg escapement method and the characterization and location of squid spawning beds.

However, the Department will need more resources than are currently available in order to begin some of the research needed to address EFI issues. The research objectives need to on data necessary to model the market squid biomass. Two gear issues need to be addressed as well: 1) the effects of fishing gear (nets, bottom lines and shackles) on squid egg beds and 2) the effects of squid lighting gear on nesting seabird rookeries.

Port samplers are important to the market squid project; however, these positions are filled by temporary personnel. To effectively monitor the fishery and maintain well trained samplers, the Department may have to develop a permanent fishery technician classification to reduce the high turnover rate of scientific aides that currently impedes research and monitoring.

In addition to the steps identified above, several more steps need to be initiated that will benefit the Department's efforts to manage market squid and other marine resources. The Department should in the next few years:

- Develop an infra-structure to facilitate communication, logistical support, standardization of data collection methods, preliminary analysis, and reporting;

- Initiate educational outreach programs;
- Assess the effectiveness of enforcement and adjust as necessary to better manage the resource (i.e., increasing penalties and/or enforcement);
- Obtain recommendations from advisory committees of the best data collection activities and models for market squid stock assessment;
- Assess relevance of previously collected data, publish for peer review, and use in management decisions; Collaborate with other state and federal agencies, academia, and the user groups to conduct EFI research; and
- Seek external funding sources;
- Encourage other researchers to address squid management needs.

These recommendations work toward providing needed EFI and bringing the Department closer to an ecosystem-based approach to the management of market squid.